Development of an Interferometric Phased Array Trigger for Balloon-Borne Detection of the Highest Energy Cosmic Particles

Completed Technology Project (2017 - 2020)

Project Introduction

Through high energy neutrino astrophysics, we explore the structure and evolution of the universe in a unique way and learn about the physics inside of astrophysical sources that drives the acceleration of the highest energy particles. Neutrinos travel virtually unimpeded through the universe, making them unique messenger particles for cosmic sources and carrying information about very distant sources that would otherwise be unavailable. The highest energy neutrinos (E>10^{18} eV), created as a by-product of the interaction of the highest energy cosmic rays with the cosmic microwave background, are an important tool for determining the origin of the highest energy cosmic rays and still await discovery. Balloon-borne and ground-based experiments are poised to discover these ultra-high energy (UHE) cosmogenic neutrinos by looking for radio emission from two different types of neutrino interactions: particle cascades induced by neutrinos in glacial ice, and extensive air showers in the atmosphere induced by the charged-particle by-product of tau neutrinos interacting in the earth. These impulsive radio detectors are also sensitive to radio emission from extensive air showers induced directly by UHE cosmic rays. Balloon-borne experiments are especially well-suited for discovering the highest energy neutrinos, and are {\it the only way to probe the high energy cutoff of the sources themselves} to reveal the astrophysics that drives the central engines inside the most energetic accelerators in the universe. Balloon platforms offer the chance to monitor extremely large volumes of ice and atmosphere, but with a higher energy threshold compared to ground-based observatories, since the neutrino interaction happens farther from the detector. This tradeoff means that the sensitivity of balloon-borne experiments, such as the Antarctic Impulsive Transient Antenna (ANITA) or the ExaVolt Antenna, is optimized for discovery of the highest energy neutrinos. We are developing an interferometric phased array trigger for these impulsive radio detectors, a new type of trigger that will improve sensitivity substantially and expedite the discovery of the highest energy particles in our universe. We have developed an 8-channel interferometric trigger board for ground-based applications that will be deployed in December 2017 with the ground-based Askaryan Radio Array (ARA) experiment at the South Pole. Preliminary Monte Carlo simulations indicate that the cosmogenic neutrino event rate will go up by a factor of ~3 with the new trigger. The true power of the interferometric trigger is in scaling to large numbers of channels, and the discovery space that is only available from a balloon platform at the highest energies is extremely appealing. We will build on and extend the NASA investment in the ANITA Long Duration Balloon (LDB) mission and the many other complementary particle astrophysics LDB missions by developing the electronics required to bring a large-scale radio interferometric trigger to a balloon platform, extending the scientific reach of any future LDB or Super Pressure Balloon (SPB) mission for radio detection of the highest energy cosmic particles. We will develop an interferometric trigger system that is scalable to O(100) channels and suitable for use on a balloon platform. Under this proposal, we will: 1) Design and fabricate interferometric trigger hardware

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Table of Contents

Organizational Responsibility

Responsible Mission Directorate:

Science Mission Directorate (SMD)

Lead Organization:

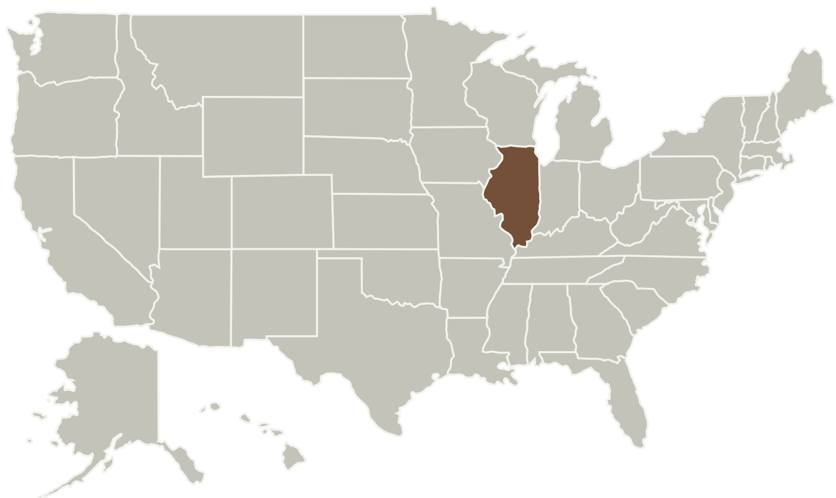
University of Chicago

Responsible Program:

Astrophysics Research and Analysis

for balloon-borne cosmic particle detectors that is scalable to large numbers of channels O(100) by reducing the power consumption per channel, increasing the number of channels per board, and developing high-speed communication capability between boards. 2) Perform a trade study and inform design decisions for future balloon missions by further developing our Monte Carlo simulation and adapting it to balloon geometries.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
University of Chicago	Lead Organization	Academia	Chicago, Illinois

Primary U.S. Work Locations
Illinois

Project Management

Program Director:
Michael A Garcia

Program Manager:
Dominic J Benford

Principal Investigator:
Abigail G Vieregg

Co-Investigator:
Carol Zuiches

Technology Areas

Primary:

- TX08 Sensors and Instruments
  - └ TX08.1 Remote Sensing Instruments/Sensors
    - └ TX08.1.1 Detectors and Focal Planes

Target Destination

Outside the Solar System